Determination of the ^{8}B Neutrino Spectrum

W. T. Winter[1,2] S. J. Freedman[1,2] K. E. Rehm[3] I. Ahmad[3] J. P. Greene[3] A. Heinz[3] D. Henderson[3] R. V. F. Janssens[3] C. L. Jiang[3] E. F. Moore[3] G. Mukherjee[3] R. C. Pardo[3] M. Paul[4] T. Pennington[3] G. Savard[3] J. P. Schiffer[3] D. Seweryniak[3] G. Zinkann[3]

[1]*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*

[2] *Physics Department, University of California, Berkeley, California 94720*

[3]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439*

[4] *Racah Institute of Physics, Hebrew University, Jerusalem, Israel 91904*

The most carefully studied component of the solar neutrino flux is due to neutrinos from the β decay of ^{8}B. The ^{8}B neutrinos account for nearly all of the solar neutrino events in water-Cerenkov experiments, which are sensitive to the differential neutrino energy spectrum. The solar neutrino data is explained by flavor oscillations and non-zero neutrino mass [1]. The neutrino oscillation solution implies that the solar ^{8}B ν_e energy spectrum is distorted. Knowledge of the primary ^{8}B neutrino spectrum is a neccessary ingredient for the proper interpretation of the solar neutrino data.

The allowed ^{8}B beta decay proceeds through a broad range of excitation energies in the alpha unstable ^{8}Be. The neutrino spectrum deviates from the allowed approximation because of the broad final state. Measurements of the alpha particle energy spectrum following the ^{8}B β^+ decay are used to determine the probability that a given excitation energy in ^{8}Be is populated, and to construct the neutrino spectrum.

We have measured [2] the total energy of the alpha particles emitted following the beta decay of ^{8}B by implanting a beam of ^{8}B ions near the midplane of a 91 μm thick planar Si detector. An implanted source eliminates the possibility of energy loss outside the sensitive region of the detector, a systematic effect in all previous measurements. The detector thickness was just sufficient to stop α particles emitted with the highest possible energy (about 8.5 MeV). Thus the full energy of both α particles was detected while the positrons deposited a minimal amount of energy. The systematic effect of positron energy was further reduced with a coincidence detector, selecting events where the positron trajectories were close to normal to the Si detector surface.

The experiment used the ATLAS superconducting linear accelerator at the Argonne National Laboratory. The ^{8}B ($t_{1/2}$=770$\pm$3 ms) beam was produced using the ^{3}He(^{6}Li,^{8}B)n reaction. The primary ^{6}Li beam, with energy 36.4 MeV, bombarded a 3.5 cm long ^{3}He gas cell. Fully stripped ^{8}B products were separated from the primary beam with a 22° bending magnet, and transported through an Enge Split Pole spectrograph. A gas-filled detector located in the focal plane of the spectrograph identified the ^{8}B products by mass, nuclear charge, and energy. The spectrograph was then adjusted so that ^{8}B ions with energies of 27.3$\pm$0.2 MeV were incident on the planar Si detector with a 13.8 mm active diameter, located adjacent to the focal plane detector. An 11 mm diameter Ta collimator masked the edges of the detector. The beam was cycled (1.5 sec on/1.5 sec off) and data taken only during the beam-off cycles. The average implantation rate was 3 ^{8}B ions/sec, and 4.5×10^5 decays were observed over six days.

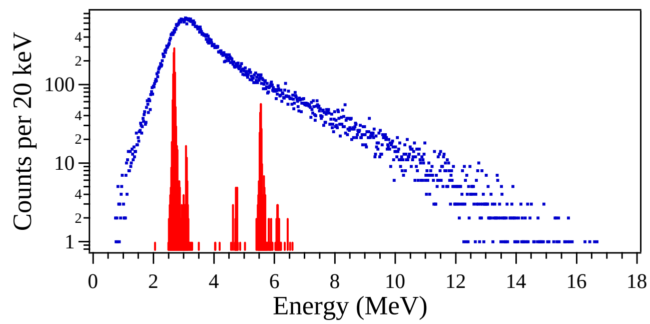

FIG. 1: The measured ^{8}B β^+ delayed two alpha spectrum (blue) shown with the ^{20}Na β^+ delayed alpha lines (red) used for calibration. The data shown here correspond to events coincident with the beta detector.

The β detector was a 2 mm thick plastic scintillator coupled to a photomultiplier tube. The detector identified a subset of events where the β particle exited the Si detector with a trajectory within 30° to normal, thus depositing a minimal amount of energy in the detector. Roughly 16% of the observed events occurred in coincidence with a count in the β detector.

The system was calibrated with implanted ^{20}Na immediately before the ^{8}B run. The ^{20}Na β^+ delayed alpha particles provided three calibration lines near the region of the ^{8}B α-spectrum peak. The ^{20}Na ($t_{1/2}$=448$\pm$3 ms) beam was produced by using the ^{19}F(^{3}He,2n)^{20}Na reaction and separating fully stripped ^{20}Na ions with energies of 170.0$\pm$1.5 MeV. As in the ^{8}B runs, the beam was cycled (1.0 sec on/1.0 sec off). An average implantation rate of 7 ^{20}Na ions/min was achieved, and over one day 1.0×10^4 decays were observed. The raw energy spectra from the ^{8}B and ^{20}Na runs are displayed in Fig. 1.

Our results disagree with the other precision alpha spectrum measurement [4]. A detailed comparison is presented in [2].

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